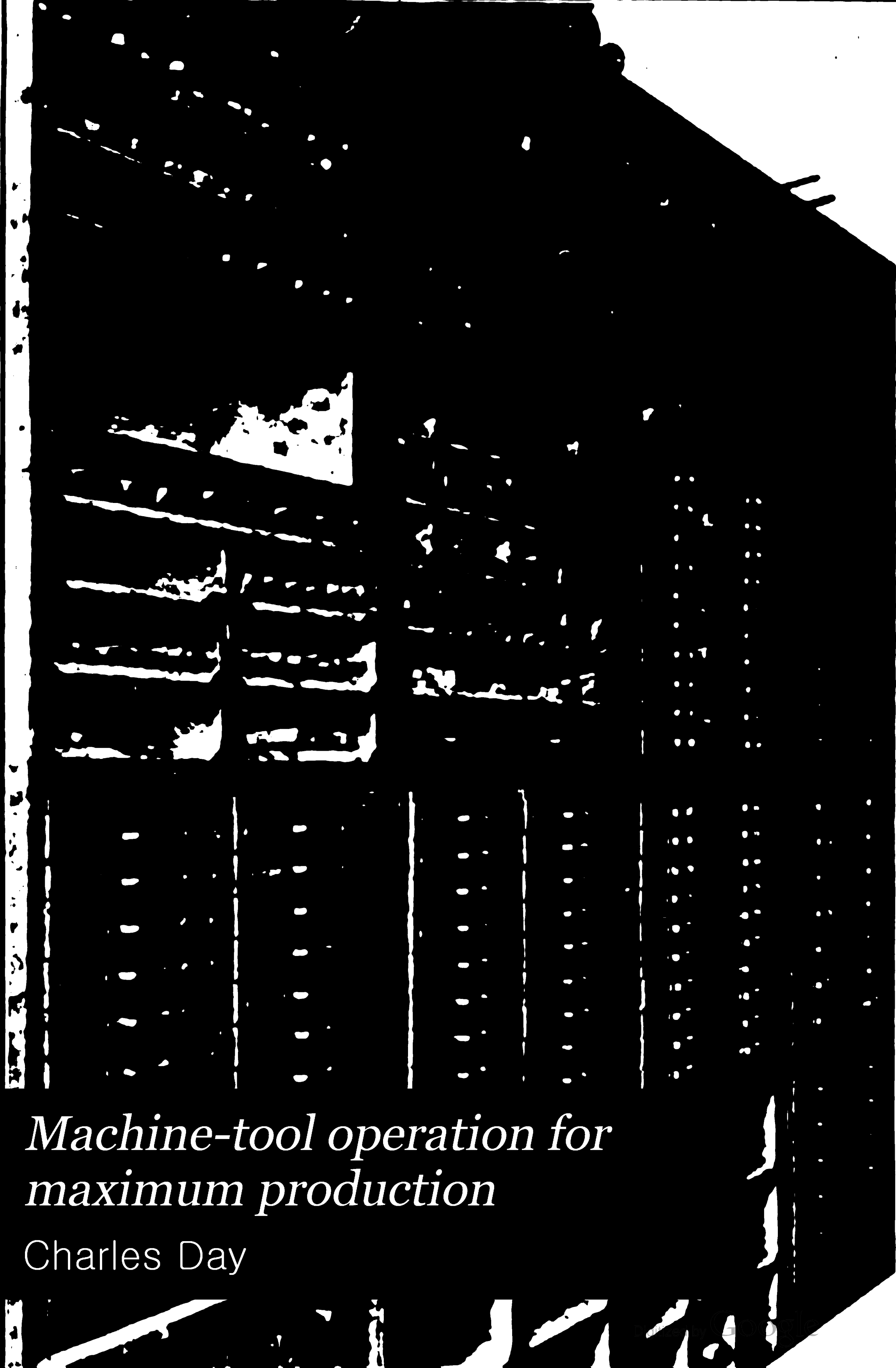


Machine-tool operation for maximum production

Charles Day

Machine-Tool Operation for Maximum Production

By CHARLES DAY

Member of the firm of
DODGE & DAY, Engineers
608 Chestnut St., Philadelphia

Reprinted from
THE ENGINEERING MAGAZINE
New York--London

MACHINE-TOOL PRACTICE FOR MAXIMUM PRODUCTION.

By Charles Day.

Mr. Day's article is the first of an important series of six, defining the settled principles of machine-shop practice for maximum production, including the design and operation of tools, the choice of equipment, the determination of processes, and the layout, construction and operation of the shops themselves.—The Editors.

MACHINE-TOOL practice for maximum production has commanded so much attention during the past few years that there is a natural hesitancy to undertake a summary of the subject in an article which must be addressed to an audience as expert as the majority of readers of this magazine. However, upon contemplating the matter, it seemed that the status of shop practice can today be somewhat more clearly defined than at any time since the advent of the high speed steels and motor drives, and possibly with this thought in mind a slightly new point of view can be had.

When one considers the important part that the metal-working industry has played in the development of present-day civilization, he is forced to conclude that the rapid evolution that it has but just undergone will reach far beyond the bounds of the shop and factory. Our attention, as a rule, is so centered upon our immediate concerns that we overlook the broader aspects of the machine-shop problem, and so lose the keen interest that must certainly spring from a realization of the substantial advancement in human progress that can be readily traced to the metal-working arts. This is a phase of the subject that we cannot afford to ignore, for the broader our understanding of the reasons governing industrial advancement and the part played by the line of work in which we are directly engaged, the more effective can our efforts be made.

The foundation of modern business and society commenced with the first general utilization of iron and steel. The advent of the railroad marked a revolution in personal and business relations, and the steamship in international affairs, and yet both of these were made possible by the work of comparatively few men. Today a very considerable part of the population of progressive nations is engaged

in business having to do with the production of metals and their manufacture; therefore, fundamental improvements in the art of metal working have a far-reaching effect. They make possible the manufacture of more useful articles at lower costs, and open new fields where satisfactory accomplishment was formerly impossible. The perfection of special steels for severe duty, and of means for working them, is creating more reliable and higher-speed train service; and modern shop practice has perfected the automobile. We have but just learned that mechanical flight has been attained, and yet the historic work of many able investigators probably would not have been consummated by the Wright brothers, notwithstanding their remarkable researches and experiments, had not advances in metal working made possible the present highly efficient hydrocarbon motor. And who will attempt to prophesy the distance and breadth that the Wrights' accomplishment may reach?

In the final analysis, the real interest attached to the performances of machinery of any kind has to do with the usefulness of the work done, and if from this standpoint the measure is not satisfactory, it has no permanent worth. Certainly, the metal trades, considered as a whole, have contributed liberally to the needs of civilization.

A study of the development of the machining of metal shows that during the period commencing with the work of Maudslay, who may be considered the father of most of our modern machine tools, and terminating only a few decades in the past, advancement had to do chiefly with the designing of new types of machines, and supplying them to the rapidly growing demand. Since that time effort has been directed principally to the more economical performance of machine work, and "efficiency" has been the watchword. For some time after the invention of the steam engine it was sufficient to make an engine that would run satisfactorily. Today, as a result of widespread competitive conditions, efficiency in operation and efficiency in manufacture are of almost equal importance.

Everyone interested in machine-shop work is familiar with the marked development of recent years. The subjects of high-speed steels, motor drives, machine tools for heavy duty, equipment for the handling of materials, and the systems of management required for directing the operators of machinery of all kinds, have been constant and at times heated subjects of debate, and the attention so given to them has, necessarily, been most fruitful of results.

It has been mentioned that shop practice, which includes all the factors just referred to, is nearing a stage approaching *standardiza-*

tion, so that a *résumé* of existing practice and a brief allusion to modern types of machinery may prove of interest.

About ten years ago there were a number of men who were actively engaged in work that had to do with the more effective administration of industrial work, and especially machine-shop work; but it is a question whether general interest would have been awakened in this subject, to anything like the extent that has proved to be the case, if certain revolutionary advances had not been made concerning the physical features involved in metal-working plants. We can properly assume that present machine-shop practice, as it is now exemplified in many concerns, received its greatest impetus through the introduction of high-speed cutting tools and the motor drive, and it is appropriate that consideration first be given to these.

The machine-shop problem, in its most elemental sense, resolves itself into one of removing chips from the parts upon which work is to be done. This is equally true whether we consider a lathe tool removing a heavy turning from a locomotive tire, a file smoothing a metal surface, an emery wheel cleaning up the face of a rough casting, or a scraper putting the finishing touches on the shears of a lathe. Tool steel is used for by far the greatest amount of work, so it should be expected that any marked improvement in its composition or method of treatment, making possible the removal of a greater quantity of chips in a given time, would result in many radical changes in shop methods. Machine equipment in use when the high-speed steels were introduced proved to be so unsuited for the new demands that it was soon clear that no half-way measure would be sufficient, but that it was necessary immediately to reconsider the whole subject of metal-working from an entirely new standpoint. Just at this time the motor drive was being strongly advocated by the companies manufacturing such equipment, and it was evident almost from the start that the individual motor drive for machine-tool operation promised a satisfactory solution to the new problems of greater power and better speed regulation. This condition resulted in a close competition for supremacy between tool steel on the one hand, and the machine tool upon the other. Another factor that proved to be important was the comparatively high cost of the new tools. To equip the tool room properly in a shop employing several hundred men required the expenditure of several thousand dollars, so that in many instances the management became insistent upon the *efficient use* of the new steels. In order to accomplish this it was found necessary to resort to much more

effective methods of management than had formerly been customary, and so the foundation was laid from which has evolved the machine-shop practice of today.

The efficiency of work performed in a machine shop, whether large or small, as a rule can be quickly arrived at through an investigation of the tool room and the department for the manufacture of jigs and other accessories; for although these departments occupy but a small part of the total shop-floor space, they serve to illustrate the policy and ability of the management. Their proper conduct involves practically all the functions that are required for the operation of the shop proper; and further, the efficiency of the productive work is to a large extent dependent upon the character and completeness of the equipment stored in the tool room.

Modern systems for shop administration may be successful, through methods of compensation, in establishing work to the full extent of physical endurance, yet this alone will not result in economic conditions. The training of the individual operators is the more essential requisite. Training, in itself, implies that the trainer must have as his object a certain definite accomplishment which can be achieved only through the standardization of methods and facilities. The competent professional baseball pitcher could never attain the proficiency now usual if the ball that he uses had not been standardized almost exactly as to weight and size. In this instance the equipment —namely, the baseball—can be readily standardized once for all, and the individual skill of the player is the governing factor. In the machine shop, however, the involved character of the equipment causes it to assume a more important part, and the operator's manual skill is not as essential as the knowledge he has concerning the method of adjusting his machine for different work. The determination of such methods can, however, be attained only as a result of painstaking scientific work, and accomplishment once achieved can only be duplicated provided the same conditions as regards tool steel, machine, and character of material worked are capable of exact reproduction. When it was found that thorough analysis and scientific study resulted, as a rule, in the establishment of methods requiring not more than one-third of the time necessary for the performance of the work when it was planned by the machinist himself, it became evident that old methods would have to give way to the new. So it is on this account that, today, standardization in regard to shop equipment is receiving just as much attention as the standardization of parts entering into the finished product.

The starting point for standardization is always in the tool room, and properly begins with the cutting tools. The adoption of standard shapes and sizes for lathe tools, boring cutters, and even chisels, is now the general practice, as is also the method of forging and treating the tools. Even in small shops it pays to have one man grind all the tools, absolutely prohibiting the workmen access to any grinder for this purpose. Tool steel is now bought by several large users according to specifications, different compositions being specified for different classes of tools, and it is likely that this practice will become general.

While what has just been said regarding cutting tools is now generally appreciated and acted upon, the same attention is not given to many other accessories which rightly form a part of the tool-room equipment. All clamping bolts and wood blocking should be standardized, and in certain cases it is now the practice always to issue, with a set of bolts, a standard wrench that exactly fits the nuts. When these bolts are returned to the tool room each one is examined, to see that it has not been damaged and that the nut is hand loose, and if this is not the case the parts are not returned to the racks until they have been repaired.

The old practice of each machinist personally securing from the tool room the tools and other auxiliary equipment that in his judgment are needed is rapidly giving way to the system of providing in advance for each operator all of the tools and other parts that are required to consummate the work in a predetermined manner. The advantage of this method is so great that to some extent at least it is being followed in almost all large shops, even though standard instructions for performing the work are not given to the workmen, or, in fact, may not be on record.

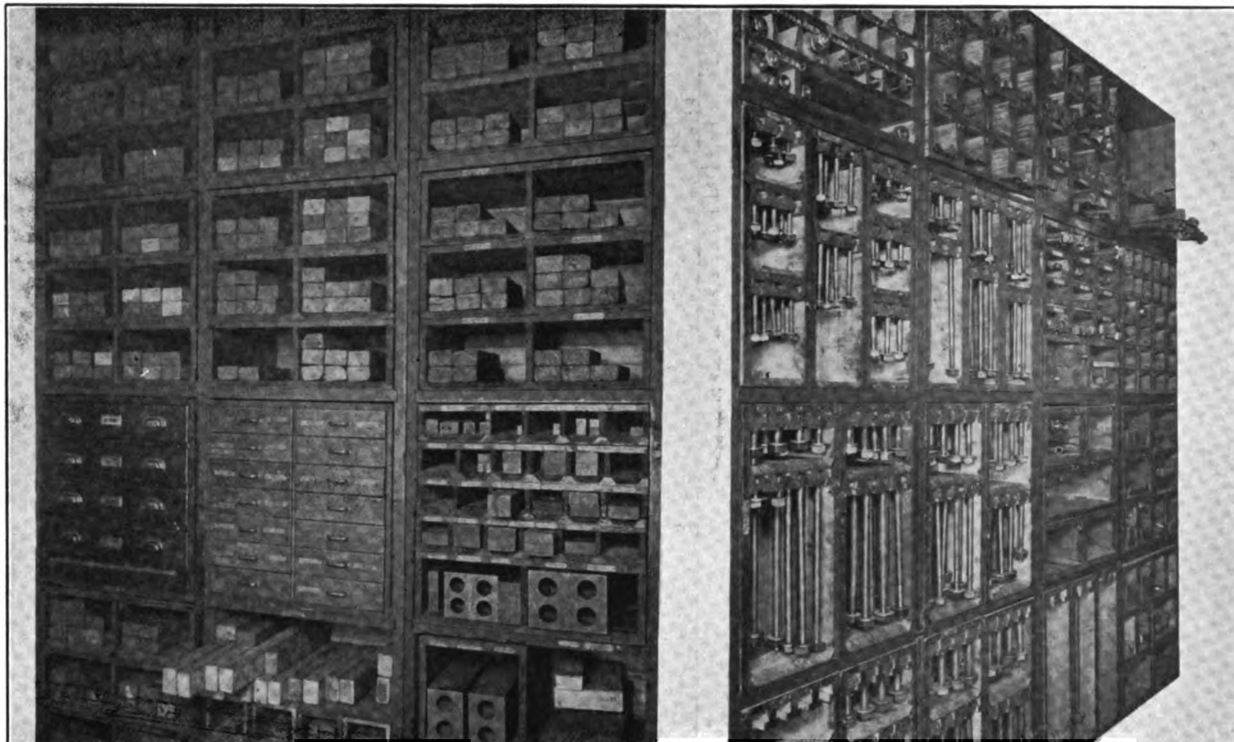
It is customary in large machine shops to confine the tool room to storage purposes only, all grinding and tool making being done in a separate department, which work in some cases is not fenced off from the rest of the shop. The desirability of this plan, as well as many other procedures that are followed in up-to-date plants, depends to a considerable extent upon the number of men employed and the character of the work. The function of the tool room, however, is always the same; and to preserve it properly it is necessary to draw a sharp line between the making, care taking, and issuing of tools, and the productive work in connection with which the tool-room equipment is used. We can conclude from the above summary regarding tool-room management that present-day practice

promises to result, very soon, in a general standardization, and that the modern tool room far surpasses in its usefulness the carelessly managed tool departments that were usual a few years ago.

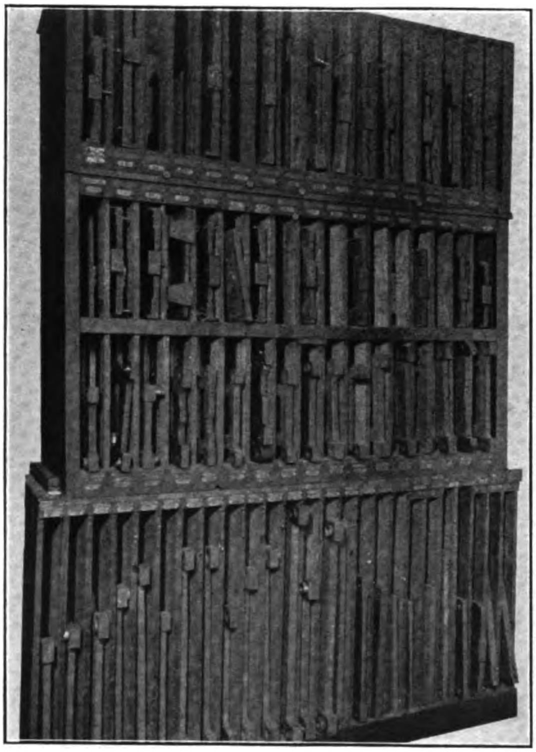
A very interesting example of the standardization of lathe and planer tools on a large scale is the central tool-dressing plant recently established at the Philadelphia Navy Yard, which supplies to all navy yards on the Atlantic Coast high-speed lathe and planer tools, which have been forged, treated and ground to standards. Each of the various yards is equipped with an automatic grinder for regrinding the tools until they require redressing, when they are returned to the central tool-dressing plant at Philadelphia for replacement by newly dressed tools. The great advantages of this scheme are that all yards are equipped with tools of standard shapes and of uniformly high quality, and as the forging, dressing, and grinding of tools are done in large lots, substantial reductions in cost result. This system for the standardization and distribution of tools was introduced at the Philadelphia Navy Yard by H. K. Hathaway, and it sets an example that will probably be followed by railroads and other large concerns operating a number of machine shops.

Owing to the importance of the question of storing small tools and accessories, a number of illustrations are included in this article which are typical of present practice. The sectional racks shown are in the tool room of the Tabor Manufacturing Company, Philadelphia, and are particularly interesting as they provide special receptacles for many parts, such as bolts, wood clamp blocks, and other auxiliary equipment which, until recently, were not standardized or carried in the tool room.

When the motor drive was placed on the market, the requirements of machine tools (that is, the requirements of the cutting tools) were so vaguely understood that the subject of individual drive proved for a long time a very complex problem, with the result that many conflicting views arose among the machine-tool designers and shop managers. However, this very condition was instrumental in rapidly developing motors adapted to a wide range of requirements, and now that the subject is better understood and opinion is in large measure unified, we find that the problem has been most satisfactorily and simply solved. The power and speed requirements of shops doing different classes of work vary widely. A jobbing shop represents one extreme, for miscellaneous work necessitates wide ranges in speeds and in power demands. At the other extreme we have



SECTIONAL RACKS, TOOL ROOM OF THE TABOR MANUFACTURING COMPANY, PHILADELPHIA.
On the left are seen the wood clamp blocks and on the right the bolts, etc., standardized for each job and methodically kept in place and in order.



SECTIONAL RACKS FOR TOOL-ROOM STORAGE OF JIGS, ETC.
Tabor Manufacturing Co.

establishments doing purely manufacturing work, such as the making of sewing machines or cash registers, in which cases the machine equipment is largely special and such changes in speeds as required are usually obtained automatically. Therefore, the shop handling miscellaneous work offers the greater opportunity for the effective use of the variable-speed characteristics of certain systems of motor drive.

It is no longer necessary for the machine-tool builder to resort to guess work in selecting motors for the operation of the tools he builds. The exhaustive tests that have been made concerning power required when machining different materials and for different combinations of speeds, feeds, and depths of cut enable him to determine power requirements with accuracy, and the character of work a given machine is designed to handle, considered along with prevailing practice regarding methods of operation, enables him to arrive at the desirable variation in motor speeds. The total range in spindle speeds that is desirable is dependent upon the ratio of maximum to minimum diameters of work, or if the work is stationary, upon the ratio of maximum to minimum cutter diameters; the range is also dependent upon the ratio of the hardest to the softest material to be machined and upon the kind of operation, whether cutting, filing, polishing, etc. The number of intermediate speeds that should be available throughout the total range is governed by the uniformity of the material worked, the uniformity of the cutters, the number of feeds, and the means that the workmen have at

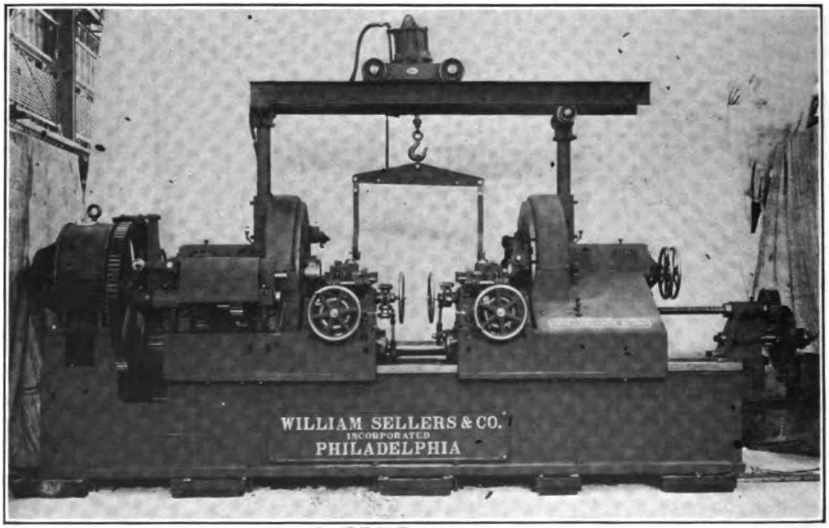
hand to determine the proper speed. The amount of power required for machines where tool steel is used depends upon the character of material and tools, the cutting speed, the depth of cut, the feed, and the shape of the cutter and the friction load. The power required for grinding machines, punching and shearing machines, and machines for changing the shape of materials without removing any metal is dependent in each instance upon factors special to these classes of work. In practically all cases, there are now available data which are sufficiently accurate to be used as a guide by the companies building machines suited to any of the purposes enumerated.

The practice of using direct-current motors for variable-speed drives has become so general that it can practically be considered standard and is not likely to be supplanted until radical changes in alternating-current motor designs have resulted. It is conceded by most men who have made a study of the subject that a range of three to one in motor speeds will satisfactorily meet most cases, and that a range of two to one is frequently sufficient. The direct-current motor of the field-weakening type will perform very satisfactorily through these ranges, and as the controlling apparatus is simple and no special system of wiring is required, this type of equipment is now being used almost exclusively.

SECTIONAL RACKS FOR ARBORS, BORING BARS, CUTTING TOOLS, ETC.
Tabor Manufacturing Co.

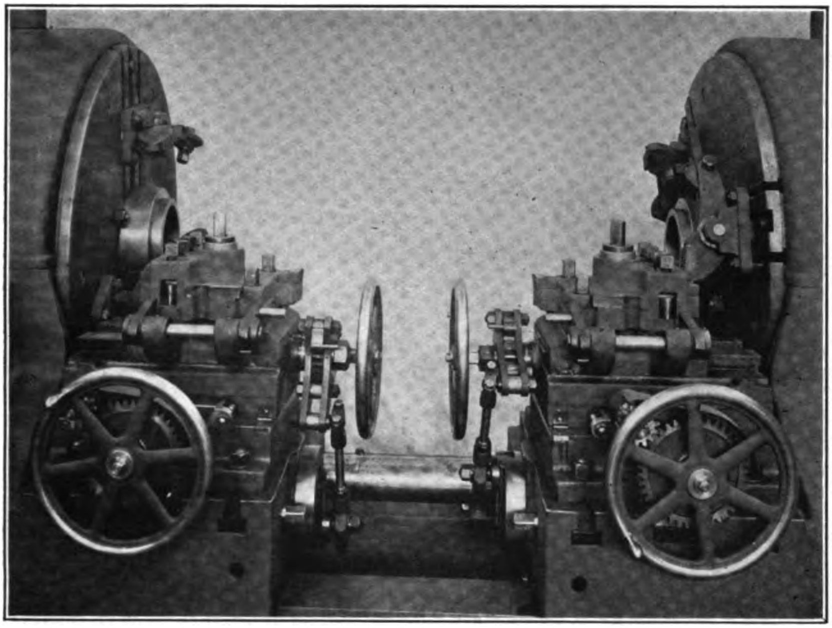
There are certain tools in almost every machine shop which can be driven advantageously by arranging in groups and belting them to short lengths of line shafting which in turn are driven by constant-

speed motors. If the shop is a small one and the requirements of certain tools can only be satisfactorily met through the use of individual motors, it is best to adopt a direct-current system throughout. The requirements of very large plants comprising a number of shops spread over a considerable area can, however, be most economically served by generating alternating current, using induction motors where constant speed will serve and direct-current motors driven from a rotary converter or motor-generator set for the variable-speed machines and traveling cranes. In this way the current can be distributed at higher voltage than would be pacticable if the direct-current system were adopted, with a consequent saving in cost of distribution. This plan has been adopted for a number of the large plants recently built, including certain railroad shops.



SELLERS WHEEL-TURNING LATHE, FRONT VIEW.
William Sellers & Co., Inc.

It will probably be of interest at this point to cite the performance of a machine tool designed with an understanding of the factors with which we have dealt and operated by a man who has been properly trained and has available all necessary information regarding the work to be performed. A case of this character was recently illustrated in the machine shop of William Sellers & Co., Inc., when a test was made upon a new car-wheel lathe designed especially to meet the requirements of railroad shops. It will be recalled by those who are familiar with railroad work that not many years ago the



NEAR VIEW OF TOOL HOLDERS AND CHUCKS, SELLERS WHEEL-TURNING LATHE.

time for turning a pair of car wheels averaged about 1½ hours, and when ten pairs could be turned out on one lathe in a working day of 10 hours it was thought that about the best possible record had been attained. This rate of work has, of course, been gradually increased since then and the results cited below exemplify the economies in time that recent methods have brought about. Three pairs of 36-inch steel-tired wheels, selected at random from a large number shipped to the machine-builders' plant by the Reading Railroad Company, were turned in an average of about 20 minutes per pair, including the time of setting, machining, and taking out of the lathe. The actual time that the machine was in operation averaged about 18 minutes per pair, and the fact that 90 per cent of the total time required represents the period that the machine was doing effective work is a very significant factor. As a rule, greater economies can be accomplished through devising means for reducing time required for setting up work and taking it out of machines than in connection with the reduction of the actual machining time. In either case the economy comprises the saving effected in wages and in the overhead expenses chargeable to the work on account of the investment in equipment and building accommodations, but the time that the machine is idle is, as a rule, not given as much attention as

the time for machining, which accounts for the substantial reduction that can often be made in this direction.

Returning to the Sellers car-wheel lathe, it will be noted by the illustrations that it is motor-driven, the direct-current, field-weakening type of equipment having been adopted. The machine was designed throughout to permit of the fullest performance of the modern high-speed steels, and the arrangements for motor control, gear changes, tool adjustments, etc., have been worked out with a view to making all of these convenient to the operator and easy of accomplishment. The tools that were used were carefully selected for the work and forged and ground to shapes that had previously been found best. The operator was thoroughly conversant with the work to be done and the handling of the lathe. He knew just how much speed the tools would stand for a given depth of cut and feed, and his training had been such that he could efficiently operate both heads of the machine simultaneously.

It was stated that the tests just referred to illustrate the high degree of efficiency that today characterizes machine-shop practice. The article that will appear in the next issue will include a somewhat more detailed consideration of machine-tool design and operation, as well as additional illustrations of modern types of equipment and motor-drive applications.

MACHINE-TOOL PRACTICE FOR MAXIMUM PRODUCTION

By Charles Day.

The article under the above title in the July issue summarized present practice regarding certain of the principal factors that have revolutionized the art of metal working and methods of shop administration. It was stated that the knowledge acquired concerning the requirements of the work and properties of the cutting tool, together with the standardization of many shop details, is but just forming a thoroughly sound basis for machine-tool design and operation. This installment will consider matters bearing more specifically upon the design, construction, and operation of machine tools.—The Editors.

IT must be remembered that in order to secure, during practical operation, the highest efficiency of the machine tools described below, the small-tool equipment must be properly cared for and a system of management enforced that provides, for each operator, directions concerning the adjustments of his machine for various jobs, and that also assures continuous movement of the parts to be machined until they are finished.

I preface this article with the foregoing remarks, as machine-tool design is no longer confined to a mere knowledge of the principles of mechanics and the properties of materials, any more than the services of the industrial engineer, engaged to prepare plans for a new machine-shop building, have to do only with the structural and architectural details that ultimately compose the building plans. An understanding of the fundamental laws underlying pure machinery design (which as a matter of fact are useful only provided the work to be done can be accurately defined) is constantly becoming the more simple part of the total information that is necessary for the designer to possess, especially as these laws are expressed in mathematical formulæ and permit of only one interpretation. It is rather his grasp of the more subtle considerations arising through a knowledge of the

subjects considered in the previous paper that measures his ability to cope successfully with the problems modern conditions have introduced. The men who lead in this field have good insight into the readiness of those who purchase machine tools to adopt departures in design and methods of operation that make for greater output, and one of the principal problems with which they are confronted is to educate the trade as rapidly as they can perfect their machines.

The questions before us may be properly divided under two headings; first, the definition of range and character of work to be performed; second, design and construction suitable for the fulfilment of specified requirements.

Radical changes in design have been brought about principally through the efforts of machine-tool builders to meet given requirements in a more efficient manner by limiting the range of usefulness of their machines, and secondarily, after the duty has been fixed, to provide means that will permit of the most efficient utilization of the high-speed steels. It is obvious that the designer must be guided almost wholly by his own judgment when arriving at a decision concerning the range of work that a given machine should handle. Much more definite data, however, are available concerning the performance of cutting tools, for the records that have been secured and the standards that have been established by machine-tool builders and the concerns manufacturing tool steel are now so complete that their maximum capabilities can be foretold within reasonable limits.

The relations existing between cutting speed, feed, depth of cut, and power requirements for various machining operations with high-speed tools when working upon different kinds of materials, are now so well understood that slide rules have been made which greatly facilitate accurate work of design. The bearing these factors have upon the power demand was referred to briefly in the preceding article under the heading of motor drives.

Mr. Fred W. Taylor's admirable treatise entitled "The Art of Cutting Metals" is deserving of the most careful study upon the part of machine-tool designers, for it not only contains data that are of immediate usefulness, but points the way for further advances through the continuance of experimental work in the same thorough and scientific manner. The metallurgical side of the subject should also be familiar to those directly engaged in the advancement of machine-shop practice, and its present status is well covered by Mr. O. M. Becker in his articles that recently appeared in this magazine.

As a result of the thorough study given to all of the foregoing matters, there is a marked tendency toward the grouping of machine

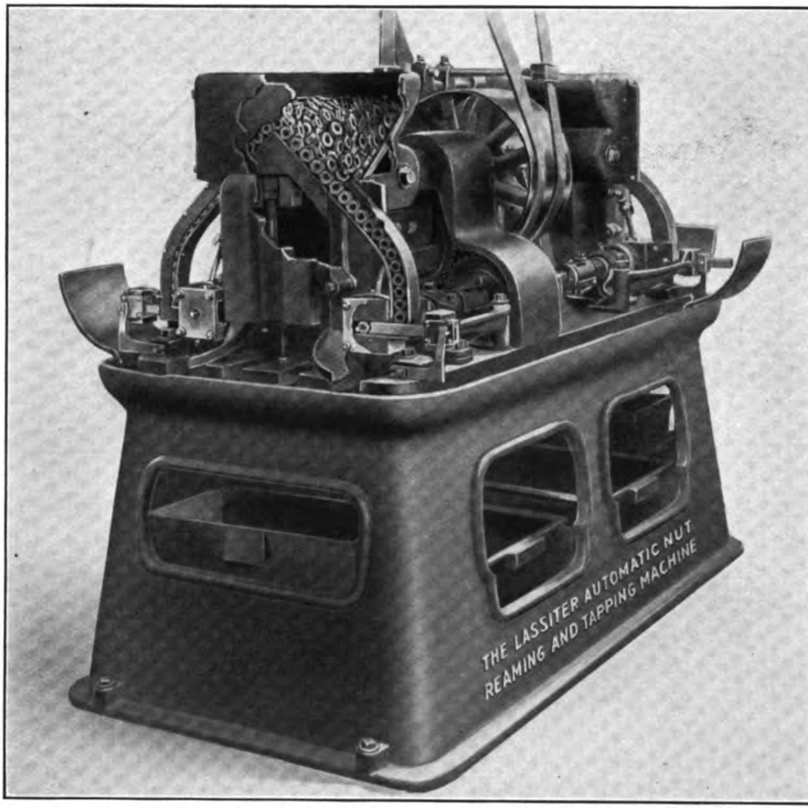


FIG. I. LASSITER AUTOMATIC NUT-TAPPING MACHINE.

tools into three broad classes; 1, fully or partially automatic machines; 2, machines of small range with limited functions; and 3, machines of broad usefulness characterized by the perfected designs of older types.

The full automatic machine tool reaches the highest efficiency in so far as facility of operation enters in, and this is a matter of much more importance than formerly as the knowledge of the most efficient method of performing each of possibly a great number of operations, necessitates constant changes in feeds and speeds. The Lassiter automatic nut-tapping machine (Figure 1) is one of the most recent examples of this type. It is hardly necessary to point out that except for the general attention that must be given to any automatic machine, it is necessary for the attendant only to put the nut blanks into the receiving hopper and take away the finished product. One of these machines in the Schenectady works of the American Locomotive Company operated during a week's run at the rate of 12,000 ½-inch

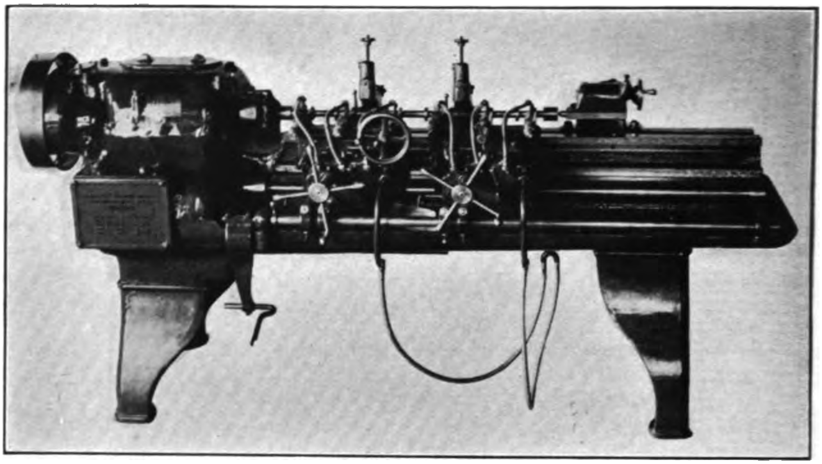


FIG. 2. FITCHBURG LO-SWING LATHE.

nuts in ten hours, and in the same period 10,000 ⅝-inch nuts. The machine in question is designed to tap and ream nuts up to 1⅛ inch. Of course, if one of the spindles is reaming and the other tapping the above output would be halved.

The field of usefulness and efficiency of the full automatic machines made by the Brown & Sharpe Manufacturing Company, the National Acme Manufacturing Company, and others is so well understod as not to require emphasis here. The same holds true of the semi-automatic machines of the Jones & Lamson, Potter & Johnson and Gisholt types, for all these have demonstrated their efficiency beyond question of doubt.

The "Lo-Swing" lathe (Figure 2) built by the Fitchburg Machine Works is a good illustration of the class of machines designed for a small range of work and, in this case, for the performance of but a single function, namely, turning on centers. The maximum diameter of work that it will handle is 3½ inches, and it is not available for chucking work or for screw cutting or any purpose other than plain turning. This limitation of duty permits of very great rigidity of construction, a condition necessary for the performance of accurate work at high speed. Space will not allow of the description of interesting points that this lathe incorporates, such as the manner of rigidly supporting the work, the tool carriages, etc. It is now generally conceded that the maximum output of a lathe is secured by taking the coarsest feed consistent with the work to be done, and owing to the limited range of the Lo-Swing design combinations of feed and speed can be had that represent almost maximum efficiency for any possible condition. The driving mechanism is designed to provide

power necessary for the performance of any reasonable roughing work falling within the lathe's capacity, so that the cutting tool has been made the limiting factor.

The value of narrowing down the available range of work can be illustrated by citing certain performances of a Lo-Swing lathe. Cam shafts having eight cams and one gear to each shaft (for four-cylinder gas engines for automobile operation) were turned from the solid steel bar in one hour each, four tools being operated at the same time. The record for this job when done on an engine lathe was several times as long. In another instance cast-steel steering knuckles used on automobiles were turned and the shoulders faced at the rate of 200 per day of 10 hours, or 3 minutes each. Ordinarily these parts, if machined on the usual type of engine lathe, would require about 10 to 15 minutes apiece. In both cases the work was done without the use of any special tools or attachments other than those furnished with the machine. I regret that it is not possible to include detail dimensions of the parts referred to.

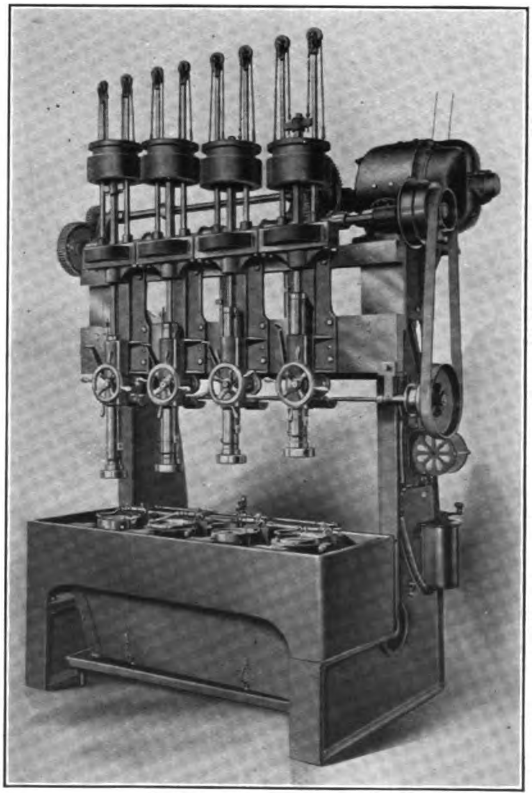


FIG. 3. LASSITER STRAIGHT AND TAPER BOLT-TURNING MACHINE.

The Lassiter straight or taper bolt-turning machine (Figure 3) was also designed for a limited range of work and for a specific function. Latest practices have been taken advantage of and its output, in practical everyday production, of 1,762 ¾-inch to ⅞-inch taper bolts 4 inches long in 10 hours (spindle speed 75 revolutions and 5/32-inch feed per revolution) and 304 2-inch bolts 16 inches long in the same time (spindle speed 40 revolutions and feed 5/32-inch per revolution) are a good

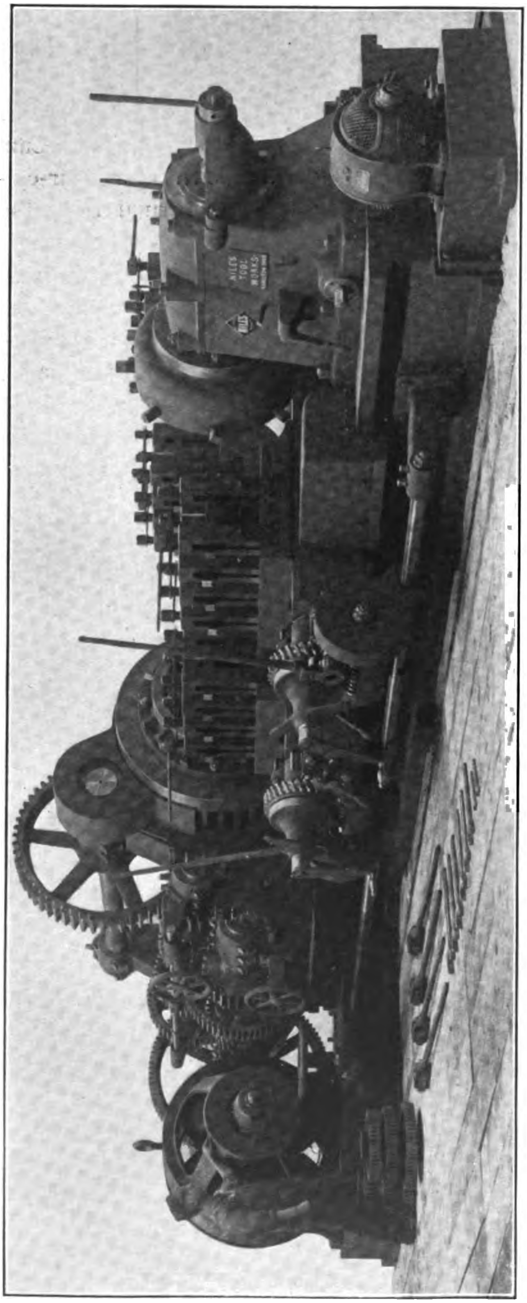


FIG. 4. NILES INGOT-SLICING LATHE.

indication of the efficiency of the result. The foregoing production is secured by roughing on two spindles and finishing on the two others.

The single-purpose principle is also exemplified for machines of a much larger class by the Niles ingot-slicing lathe (Figure 4). It is provided with sixteen cutting tools, eight on the front and eight on the rear of the machine, and each pair of front and rear tools work in the same cut or groove, the rear tool cutting out a narrower groove than the front one. The machine is designed to handle ingots up to 24 inches diameter and the range of spindle speeds is 1.6 to 18 revolutions per minute. Its gross weight is about 110,000 pounds exclusive of motor drive. The builders recommended a 90 horse power motor of the

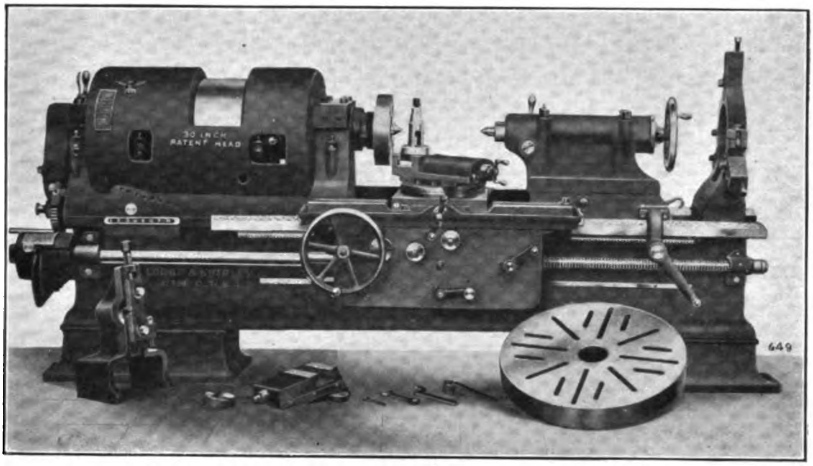


FIG. 5. LODGE & SHIPLEY 30-INCH PATENT HEAD LATHE.

direct-current type with a speed variation of two to one. The function of this machine is made clear by the illustration, and its massive design is indicative of the service to which it is subjected.

The above illustrations were included principally to emphasize the importance of the initial definition of work to be handled as a factor in the design of machine tools for maximum production. Almost any work can be economically performed upon full automatic

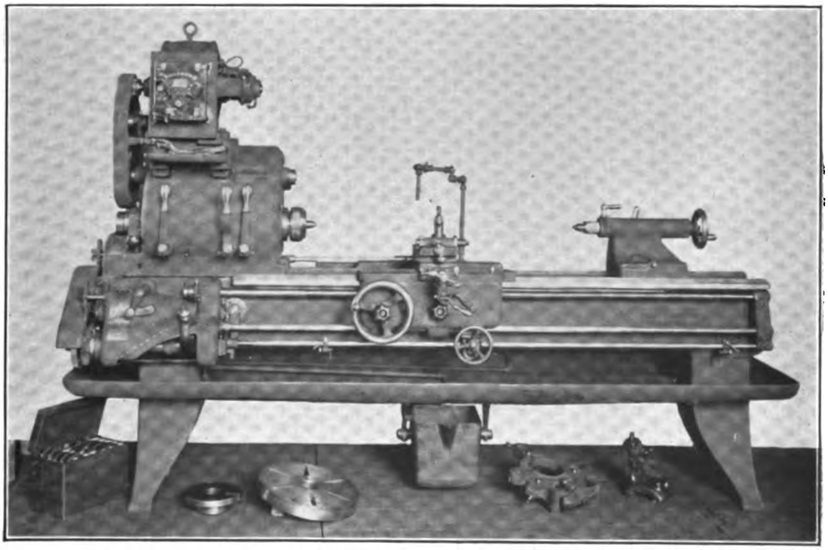


FIG. 6. PRATT & WHITNEY 16-INCH MOTOR-DRIVEN ENGINE LATHE.

machines provided the same operations can be repeated a great number of times. Modern practice, however, has made it possible to curtail greatly the machine time for many parts that are made in limited numbers only.

There will always be a field of usefulness for machines of all classes designed for a wide range of work, because in many shops little opportunity for duplication exists and for the performance of work upon large parts highly specialized machines can rarely be kept sufficiently busy to justify the large investment charges. The

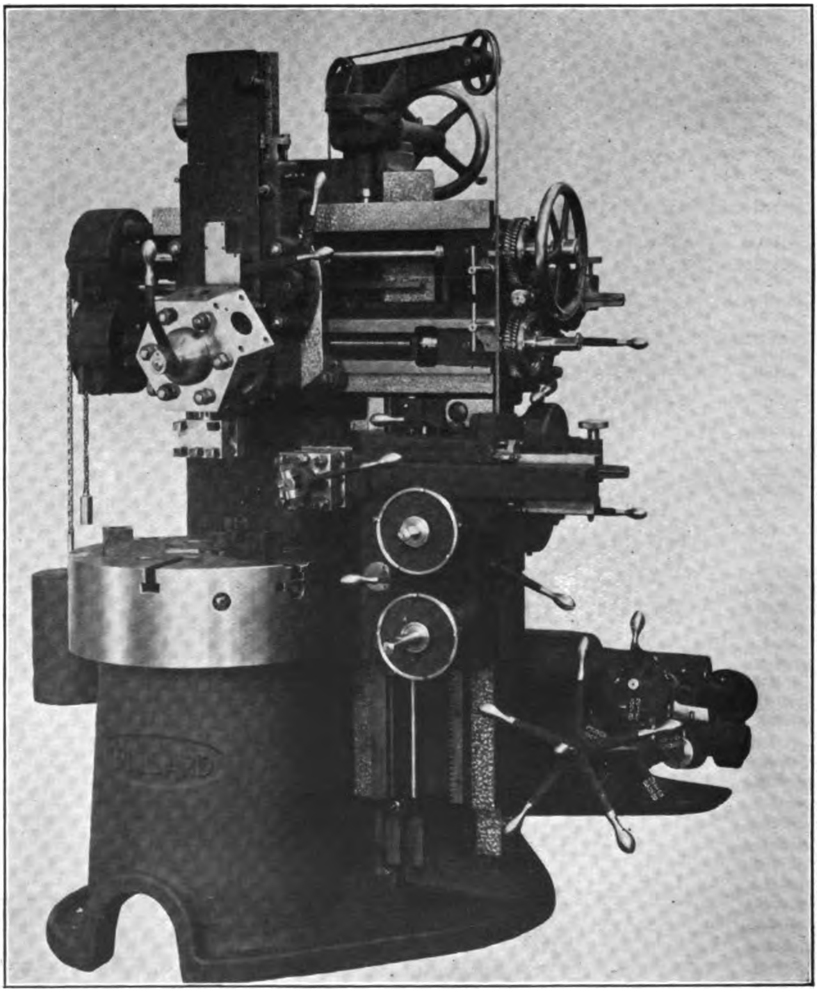


FIG. 7. BULLARD 24-INCH VERTICAL TURRET LATHE.

machines illustrated by Figures 5 to 20 inclusive serve to exemplify the advance that has been made in machines of standard types without curtailing the range of work that can be accommodated.

The Lodge & Shipley belt-driven lathe (Figure 5, page 731) was selected for the purpose of exemplifying the type adapted to the broadest conditions, as opposed to the single-purpose lathe. The replacement of the cone-pulley drive by the change-gear transmission which has been so generally effected in machines of all types is well illustrated by the patent head which readily transmits power for maximum demands and in conjunction with the countershaft a consistent number of speeds can be secured. In addition, one of the most desirable features of this type of transmission is that it necessitates a minimum effort upon the part of the operator when changing speeds, and it thus represents a great advance over the step-cone pulley drive.

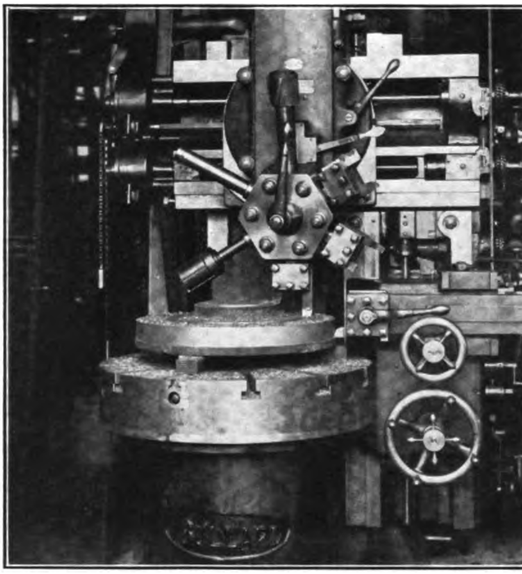


FIG. 8. BULLARD VERTICAL TURRET LATHE SET UP FOR A JOB.

This problem of facility of operation is most difficult to solve for machines suited to a wide range of work, although very great progress has been made during recent years. It is an especially important matter for large machines as the unit charge for setting up and taking down work is proportionally large on account of the high machine-hour rate. It is in this regard that the standardization of tee slots, clamping bolts, blocking, and special means for handling heavy parts plays such an important function.

The 16-inch motor-driven engine lathe built by the Pratt & Whitney Company (Figure 6) is a good example of the latest practice in small lathe construction.

An excellent illustration of machines designed for a wide range of duty is the Bullard vertical turret lathe described by the Bullard Machine Tool Company as "A multi-purpose machine tool of almost

universal adaptability for pieces coming within its range." The 24-inch machine is shown in Figure 7, and the setting of the tools for a given job by Figure 8. Although this vertical turret lathe accommodates a very great variety of work, and a considerable range in sizes, efficiency has by no means been sacrificed, but rather has the opposite result been brought about through a design that permits, in some cases, of the simultaneous operation of four tools on a single piece and that minimizes idle time through the facility afforded when making adjustments. The single-column box construction with broad base, well ribbed throughout, is suited to resist strains and eliminate the chatter which is so destructive to the cutting tool. The convenience of the gear change drive is taken advantage of to the full.

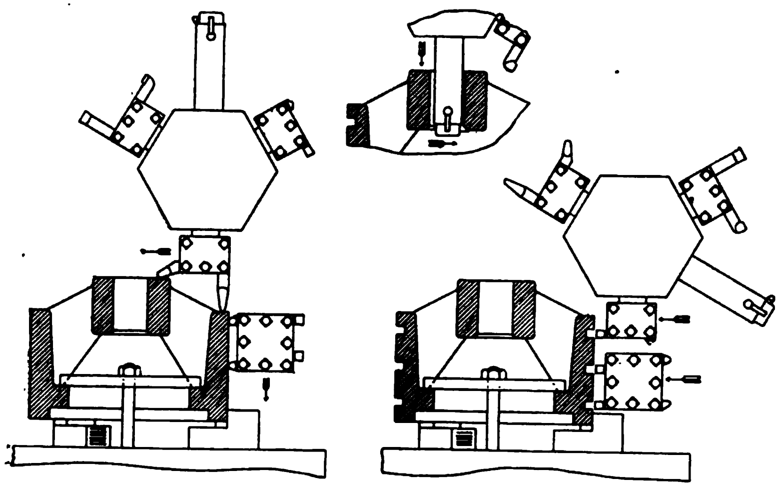


FIG. 9. OPERATIONS PERFORMED ON CAST-IRON PISTON HEAD WHEN MACHINED ON BULLARD VERTICAL TURRET LATHE.

Fifteen table speeds arranged in geometrical progression can be secured without stopping the driving pulley and a brake is used to check idle revolutions of the table. The control of the machine has been centralized to a very great extent and interlocking devices are used to obviate break-downs. The independent universal movement of both vertical and side heads permits of the use of single point rather than formed tools, and in the words of the maker "a four-inch gear blank and a fly-wheel requiring the full capacity of the machine may be completed with equal facility with the same tool equipment." The feed gears are independent for each head and micrometer dials and observation stops add to the completeness of the design.

In many respects this machine illustrates well the trend of machine-tool practice, and on this account it has been described in some

detail. Figure 9 shows the operations performed when roughing a cast-iron piston head (18-inch diameter, 10-inch space) to within 1/16 inch of finished size. The time for this job is 45 minutes. The finishing cut is taken after the head is forced upon the rod.

Aside from the defining of work to be done and the manner in which it should be performed, modern practice has been concerned chiefly with the severe duty exacted by modern cutting tools. It was soon found that their maximum performance taxed the materials that were formerly used for machine-tool construction beyond the point where satisfactory operation is possible. The machine-tool builder profited considerably in regard to this matter through the experience of the automobile makers, for the heavy moral responsibility which rests upon the latter made it imperative that they should satisfactorily meet the duty imposed upon the materials of construction—that is, lightness without sacrificing toughness and strength. Gears and shafts made of nickel-, vanadium-, chrome- and other alloy-steels are now used in both these businesses, so that it is absolutely necessary that the designer be thoroughly conversant with their known properties, and in touch with advancement work that is going rapidly forward. Much of interest and value concerning this subject will be found in the paper by John Mathew published in the *Journal of the Franklin Institute,* May 1909.

Almost any of the modern machine tools could be used to illustrate the changes that have been necessary in the details of construction in order that they may withstand present day demands. The new Cincinnati Bickford high-speed plain radial drill press illustrates interestingly the recent progress made in high-speed drilling. The 72-inch machine weighs approximately 21,000 pounds and is equipped with a 20 horse power type S, Westinghouse constant-speed motor. The transmission is composed of nickel-steel gearing, and twenty different spindle speeds arranged in geometrical progression are secured by means of a speed box, operated by a single lever and four changes on the head. A lever in reach of the operator actuates the only friction clutch in the transmission which is used to start, stop and reverse the spindle. The feed box and certain other features distinctive of former Bickford radials are incorporated in the machine, although they have been redesigned to suit the extraordinary requirements. Eight feeds are provided, arranged in a geometrical progression from .006 inch to .048 inch per revolution of the spindle. The sizes of shafts and bearings, features of lubrication, and other details have been worked out with much care, and especially the structure of the bed, column and arm, so as to secure great rigidity during maximum work.

I recently observed certain tests on this machine and the results are worth recording. A number of 3-inch holes were drilled through a block of cast iron 4 inches thick with a Celfor drill operating at 187-feet cutting speed in about 35 seconds, or at a feed of 6¾ inches per minute. The same radial drill press operated a ½-inch Celfor drill at 70-feet cutting speed and a feed of 27 inches per minute, the cast-iron blocks being drilled through in less than 9 seconds. Of course the cutting speed during the first test was abnormally high, although the drill was in good condition after the work was done. In the latter instance the drill was apparently perfect after drilling a very large number of holes. Over 20 horse power was required to drill the 3-inch hole at the rate mentioned, exemplifying a condition of operation that would have been scarcely conceivable a few years ago. The extensive experiments that the designer, Mr. H. M. Norris, has conducted regarding the drilling of metals formed the basis for the design of this radial, so that the problem was one of satisfactorily meeting known requirements.

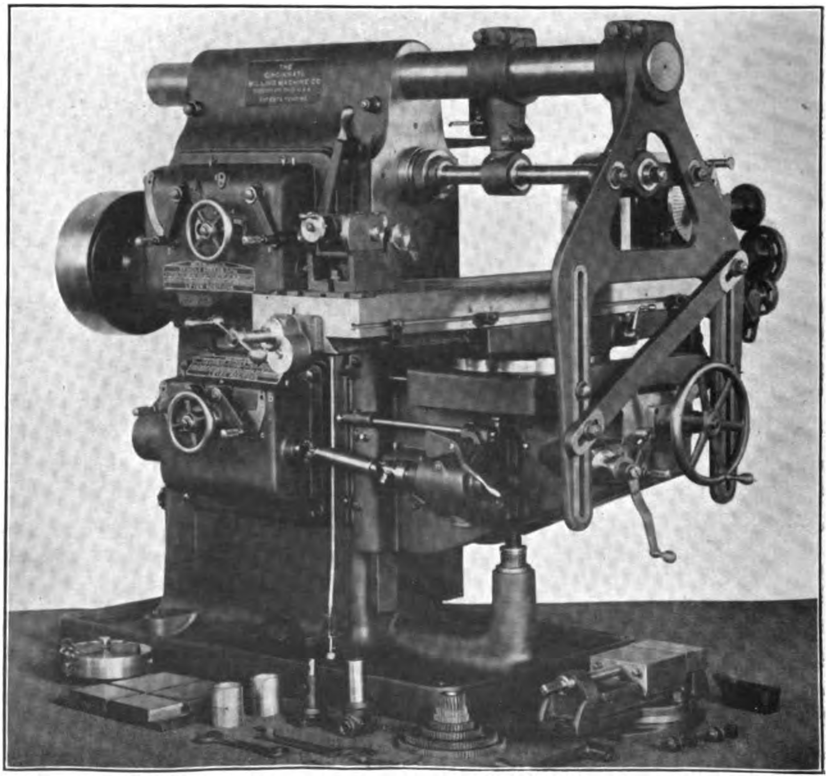


FIG. 10. NO. 5 UNIVERSAL HIGH-POWER MILLER. CINCINNATI MILLING-MACHINE CO.

Tests recently made by Mr. Geo. E. Hallenbeck indicate that the most rapid drilling can be done by using comparatively high speed and moderate feeds, as it is possible to carry a heavier feed at a high speed than at a medium speed. Mr. Hallenbeck's tests were made on a modern Baker Brothers' drill press and showed results that checked with the test on the ½-inch drill described above.

Machine-shop practice has made noteworthy progress in regard to milling work. Figures 10 and 11 show the No. 5 universal high-power miller and, in part, the No. 4 vertical high-power miller built by the Cincinnati Milling Machine Co.

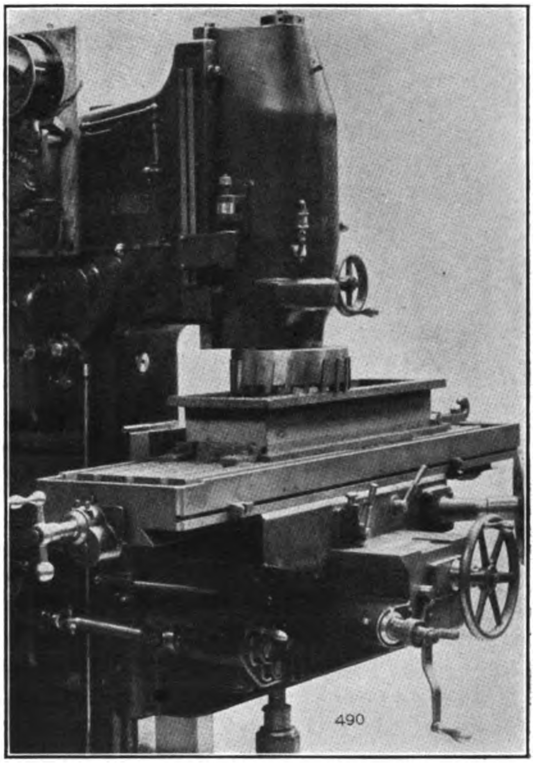


FIG. 11. NO. 4 VERTICAL HIGH-POWER MILLER, CINCINNATI MILLING MACHINE CO.

This concern has established a fixed duty at the cutter as the basis of design for each of their milling machines. Extensive cutting tests were conducted for the purpose of determining these standards, which are based upon the milling of machinery-steel blocks 5 inches square and 18 inches long, analyzing 16 points carbon and 51 points manganese; tensile strength 55,000 pounds per square inch, elongation 50 per cent. The No. 4 miller when equipped with a standard spiral milling cutter with nicked teeth will take a cut across one of these blocks 5 inches wide and ⅛ inch deep, at a table speed of 9¼ inches per minute, which is at a rate of 6.1 cubic inches of metal removed per minute. This practice, which is also being followed by certain other machine-tool builders, is rapidly tending to place the sale of equipment solely upon a basis of the quantity and quality of work that it can produce, rather than upon a comparison of the structural

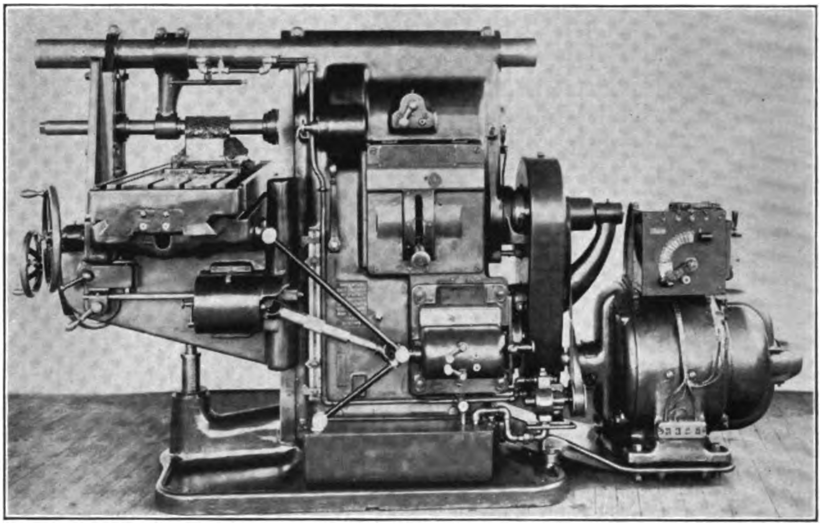


FIG. 12. NO. 5 HEAVY PLAIN MILLING MACHINE. BROWN & SHARPE MFG. CO.

features, which is often quite misleading to those not familiar with the principles of design.

Interchangeability of parts between horizontal and vertical types of milling machines and for different systems of drive and feed is now recognized as important to the purchaser, and the Cincinnati Milling Machine Company have satisfied this condition very efficiently.

The possibilities of modern milling-machine design were nicely shown by the operation of a Brown & Sharpe No. 5 heavy plain milling machine (Figure 12) exhibited at the Master Mechanics' Convention during June of this year. The floor upon which the machine was set up without bolting, settled 1¼ inches after being loaded. In one instance high-speed cutters, 3¾ inches diameter with spiral nicked teeth, milling carbon steel (65,000 tensile strength and about 40 points carbon) operated satisfactorily at a cutting speed of 60 feet per minute, width of work 6 inches, depth of cut 3/16 inch, and table feed 16 inches per minute. A number of delicate tests were made during the performance of this work to demonstrate the rigidity of the machine. The same gang of cutters made over one hundred cuts across the test piece under the conditions enumerated and their life was by no means reached, their capacity being probably in the neighborhood of 200 cuts.

The feeds and spindle speeds provided for in this machine are arranged in geometrical progression and are independent. The feeds are all given in inches per minute so that after the cutter has been brought up to the proper peripheral speed the feed can be readily

adjusted to the point best suited to the nature of the work and type of cutter used. This practice in itself represents quite an advance in milling-machine design, and is followed by the builders of not only the types of machines illustrated but those for other purposes.

Figure 13 shows the Brown & Sharpe No. 6 automatic gear-cutting machine which is referred to in this part of the article on account of its interest from a standpoint of milling operations. It has been gradually modified since it was put upon the market years ago, to meet the advances made in high-speed cutters, and in this respect is a good example of the evolution through which machine tools must go in order to keep abreast of the times. An interesting piece of work was recently performed on this gear cutter in the shop of the Brown & Sharpe Mfg. Co. A cast-steel gear, 119 teeth, 2-inch pitch, 5-inch face, was finished from the solid without previously roughing with a

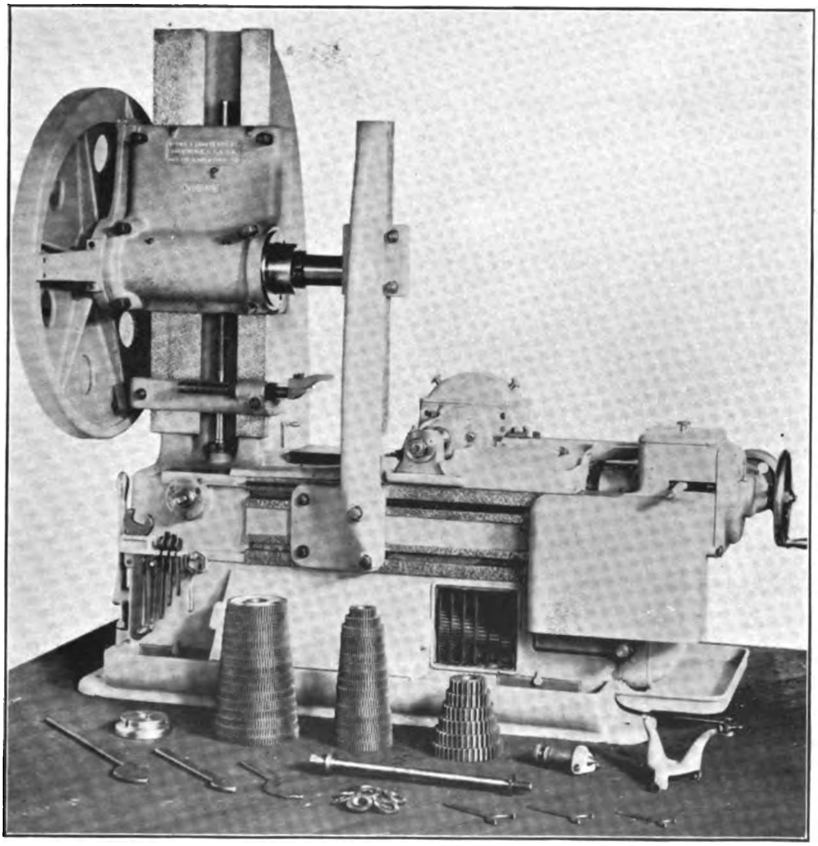


FIG. 13. BROWN & SHARPE NO. 6 AUTOMATIC GEAR-CUTTING MACHINE.

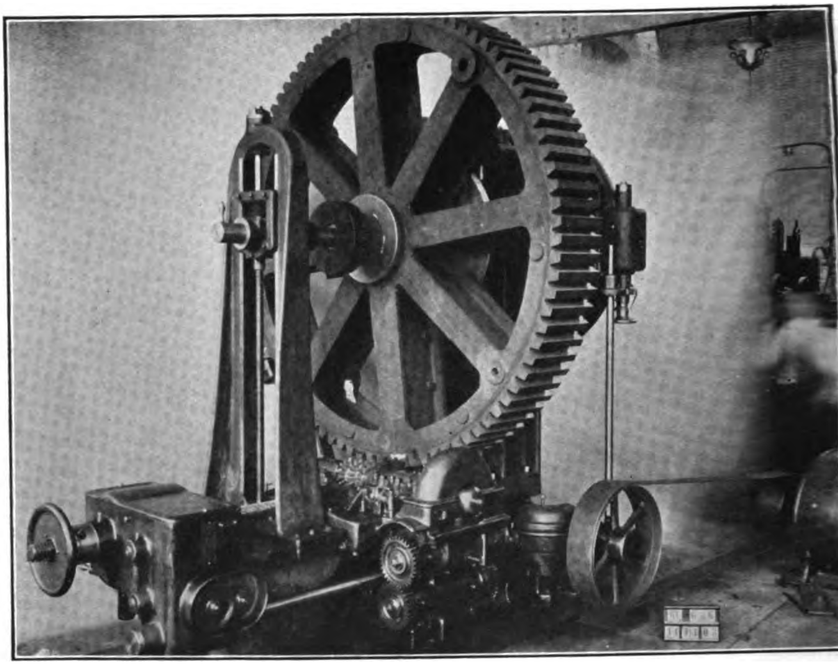


FIG. 14. GOULD & EBERHARDT 84 BY 16 IN. NEW TYPE AUTOMATIC GEAR CUTTER.

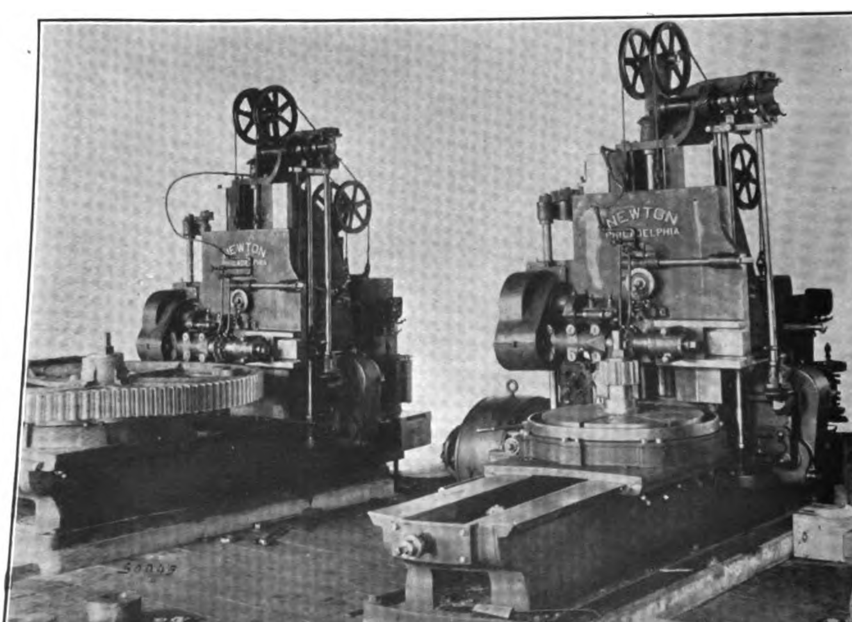


FIG. 15. NEW RAPID-PRODUCTION SPUR-GEAR CUTTING MACHINE. NEWTON MACHINE TOOL WORKS.

6½-inch diameter high-speed steel cutter, the spindle revolutions being 38 per minute and the feed 1 15/16 inches per minute. The cutting time per tooth was 4 minutes and the time for the entire gear 8 hours and 13 minutes. In no case did the teeth vary more than 0.001 inch, a degree of accuracy well within the requirements of commercial gear cutting.

Figure 14 illustrates the 84-inch by 16-inch Gould & Eberhardt new type automatic gear-cutter for blocking out a large cast-iron gear. This gear has 90 teeth, 3 inches circular pitch, 87.86 inches outside diameter and 12 inches face. The total time for blocking out and finishing was 7 hours and 35 minutes.

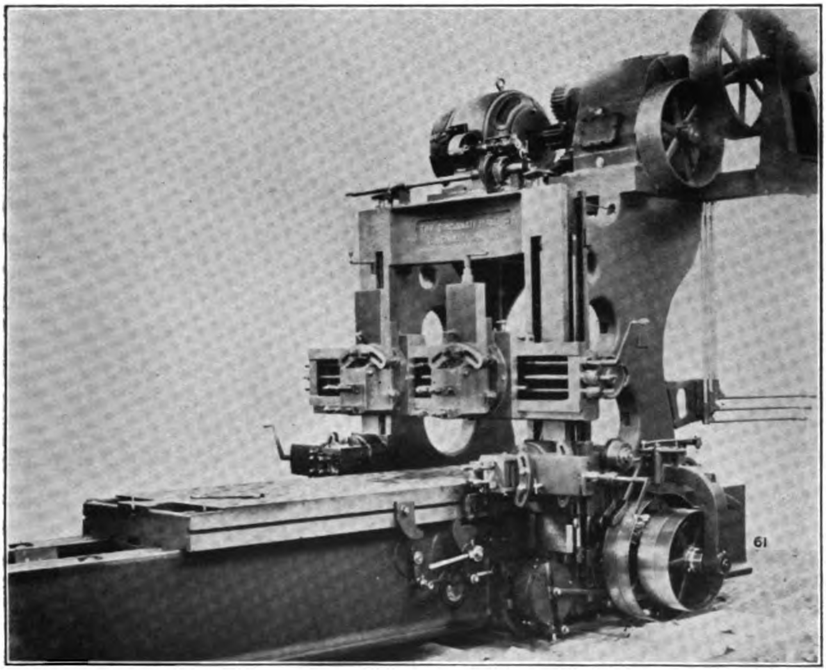


FIG. 16. 42-INCH VARIABLE-SPEED MOTOR-DRIVEN FORGE PLANER. THE CINCINNATI PLANER CO.

Figure 15 illustrates the new rapid production spur-gear cutting machine built by the Newton Machine Tool Works, and very interesting performances have been accomplished on this machine.

Brief reference should be made to machine tools of the reciprocating type, such as planers, shapers, and slotters,. especially as these, considered as class, were not redesigned to meet new conditions as promptly as the types we have already considered. As no change in cutting speed is required on account of the dimensions of the work, it was some time before its need in order to meet the requirements of

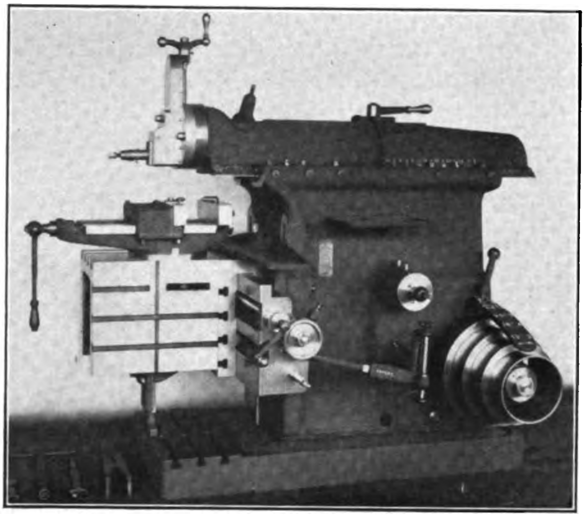


FIG. 17. GOULD & EBERHARDT 24-INCH SHAPER, HIGH-DUTY.

different materials and different kinds of cuts was properly appreciated. Much importance has been attached to the speed at which the work is returned, whereas a simple calculation will at once show that a variable cutting speed is a far more important matter. For example, with a cutting speed of 20 feet per minute and a return speed of 80 feet per minute, the cutting feet per hour would be 960. If the speed of the return is doubled (160 feet per minute) the cutting feet per hour would be 1,066, or a gain of 11 per cent. On the other hand, if the cutting speed is doubled (40 feet per minute) and the return kept at 80 feet per minute, the cutting feet per hour would be 1,600, or a gain of 66 2/3 per cent.

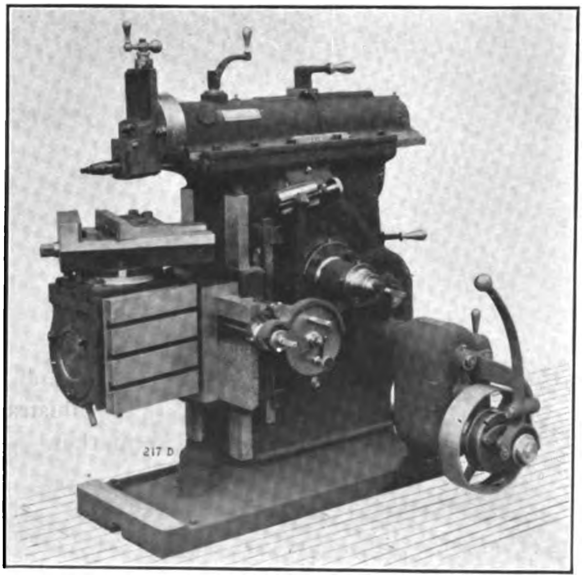


FIG. 18. GEARED SHAPER, 16-INCH, WITH FRICTION CONTROL FOUR-SPEED DRIVE. AMERICAN TOOL WORKS CO.

This fact is fully recognized in the design of the machine illustrated in Figure 16 which is the 42-inch variable-speed motor-driven forge planer built by the Cincinnati Planer Co. The motor is rated

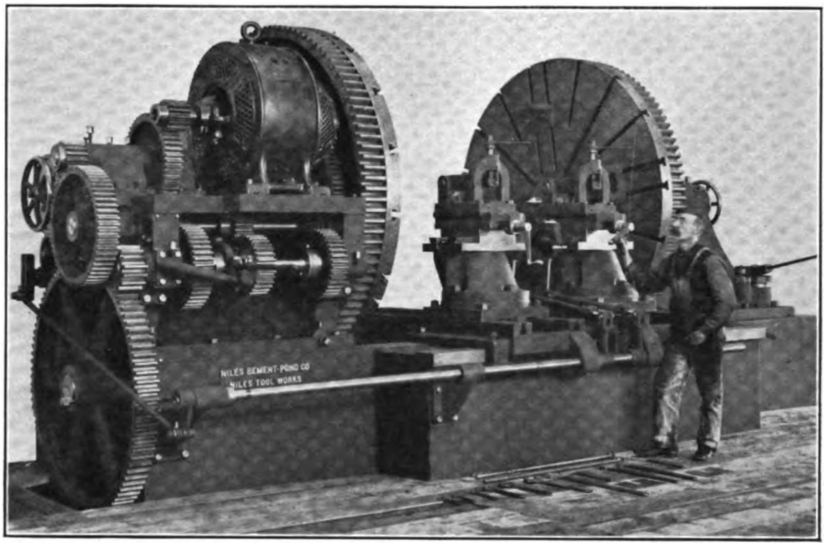


FIG. 20. NILES 90-INCH DRIVING-WHEEL LATHE.

at 20 horse power and is the compound-wound direct-current type. The return speed is fixed at 80 feet per minute and cutting speeds of 15, 20, 25, 30, 35, 40 feet per minute can be had by means of the positive variable-speed drive mounted on the housings. In the main particulars this illustration is self explanatory.

Figures 18 and 19 illustrate respectively the shapers built by Gould & Eberhardt and the American Tool Works Company. Each of these machines possess features that adapts it to the requirements of high-speed work.

Figure 20 is included as an example of the modern equipment which has been perfected to meet the severe service exacted in modern railroad shops.

A full realization of the advance that has been made in machine-tool practice during recent years can be had only by making a minute study of the subject. Many seemingly unimportant details have contributed largely to the success of individual types of machines, and I regret that it has been necessary in this article to select, as illustrations, only a few of the many admirable machines on the market.